

## **New dinosaur discoveries in the Jurassic and Cretaceous of northeastern Thailand**

Eric Buffetaut<sup>1</sup>, Varavudh Suteethorn<sup>2</sup>, Haiyan Tong<sup>1</sup>,  
Yaowalak Chaimanee<sup>2</sup> and Sasidhorn Khansubha<sup>2</sup>

<sup>1</sup>UMR 5561 du CNRS (Université de Bourgogne). Present address: Laboratoire de Paléontologie des Vertébrés, Case 106, Université Paris 6, 4 place Jussieu, 75252 Paris Cedex 05, France.

<sup>2</sup>Geological Survey Division, Department of Mineral Resources, Rama VI Road, Bangkok 10400, Thailand.

### **ABSTRACT**

Recent discoveries of dinosaurs in northeastern Thailand are reviewed. The first dinosaur remains from the Phu Kradung Formation (Late Jurassic) are isolated teeth of a theropod and a sauropod with spoon-shaped teeth reminiscent of the Chinese Euhelopodidae. A new dinosaur footprint site discovered in the Phra Wihan Formation (Early Cretaceous) shows a trackway left by a large theropod. New dinosaurs from the Sao Khua Formation (Early Cretaceous) include the early and primitive tyrannosaurid *Siamotyrannus isanensis*, and a still unnamed small ornithomimosaur with a relatively advanced foot structure. The remarkable dinosaur locality at Wat Sakawan (Changwat Kalasin) has yielded several more or less complete skeletons belonging to the sauropod *Phuwiangosaurus sirindhornae*. Jaws and teeth from Wat Sakawan referable to *Phuwiangosaurus* are reminiscent of those of the Late Cretaceous sauropod *Nemegtosaurus* from Mongolia. A second sauropod, with large spoon-shaped teeth, is also present at Wat Sakawan. The first iguanodontid remains (teeth and a vertebra) to be reported from Thailand have been found in the Khok Kruat Formation (Aptian-Albian); they probably indicate immigration from Europe.

Since we published our last reviews of dinosaur discoveries in Thailand in 1995 (Buffetaut, Suteethorn *et al.*, 1995; Suteethorn *et al.*, 1995), a number of significant new finds and advances have taken place, so that it seems justified to update these review papers by presenting some of the recent results of our Thai-French group. Although the most spectacular discoveries have been made in the Sao Khua Formation, important finds have also been made in the Phu Kradung, Phra Wihan and Khok Kruat Formations and deserve to be briefly described here.

**Phu Kradung Formation: the first Jurassic dinosaurs from Thailand**

Because the Sao Khua Formation, which is the most productive formation of the Khorat Group in terms of dinosaur remains, was long held to be Late Jurassic in age, until recently it was accepted that the Jurassic record of dinosaurs in Thailand was remarkably good. However, the palynological studies of Racey *et al.* (1994, 1996), confirmed by fission track studies (Bristow *et al.*, 1994), have conclusively shown that a large part of the Khorat Group, including the Sao Khua Formation, must be placed in the Early Cretaceous - which in many ways is in better agreement with the general character of the dinosaur fauna of the Sao Khua Formation as we now know it. This, however, meant that no Jurassic dinosaurs were known



from Thailand, since there was a long gap in the Thai record between the Late Triassic prosauropod from the Nam Phong Formation (Buffetaut, Martin *et al.*, 1995) and the dinosaur footprints known from the Early Cretaceous Phra Wihan Formation. Jurassic vertebrates, such as the large crocodilian *Sunosuchus thailandicus* (Buffetaut & Ingavat, 1984) and a temnospondyl amphibian (Buffetaut *et al.*, 1994) were known from the Phu Kradung Formation, but no dinosaur remains had been reported.

In 1996, a new vertebrate locality was discovered by our group in the Phu Kradung Formation at Ban Khok Sanam (Amphoe Phra Moen, Changwat Kalasin), and dinosaur teeth were found there in 1996 and 1997. Besides dinosaurs, the locality has yielded fish scales, a lungfish toothplate, a vertebra of a temnospondyl amphibian, turtle plates, and crocodilian teeth and scutes. The dinosaur teeth belong to two different types :

**-Theropoda :** these carnivorous dinosaurs are represented by a single laterally compressed and serrated tooth. The specimen is 25 mm high and does not allow a precise identification.

**-Sauropoda :** these herbivorous dinosaurs are represented by two teeth, one of them very incomplete. The best preserved tooth (height : 27 mm) shows a broad spoon-shaped asymmetrical crown, with a concave lingual surface and a convex labial surface (Fig. 1). The enamel is finely wrinkled, especially near the base of the crown. Wear facets are visible at the apex and on the labial surface. This tooth is very different from the much narrower teeth of *Phuwiangosaurus sirindhornae* from the Sao Khua Formation (see below). It resembles the posterior teeth of Jurassic sauropods from China, notably *Euhelopus* (Wiman, 1929) and *Mamenchisaurus* (Russell & Zheng, 1993), which are placed in the family Euhelopodidae. This resemblance suggests that a euhelopodid was present in South East Asia in the Jurassic, which is not surprising from a palaeobiogeographical point of view, since other faunal elements from the Phu Kradung Formation, such as the crocodilian *Sunosuchus* (Buffetaut

& Ingavat, 1984), also have their counterparts in China.

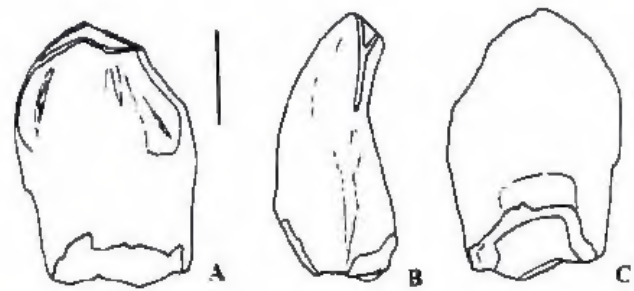


Figure 1 Tooth of a sauropod dinosaur from the Phu Kradung Formation (probably Late Jurassic) at Ban Khok Sanam (Changwat Kalasin), in lingual (A), anterior (B) and labial (C) views. (sketch by H. Tong). Scale bar : 1 cm.

### New dinosaur footprints from the Phra Wihan Formation

The Phra Wihan Formation, which is palynologically dated as early Early Cretaceous (Racey *et al.*, 1994, 1996), has so far yielded no fossil bones. At Hin Lat Pa Chad, in the Phu Wiang Hills, an exposure of Phra Wihan Formation shows several trackways of small dinosaurs (Buffetaut & Suteethorn, 1993). In 1996, more dinosaur footprints were discovered by two schoolgirls in the Phra Wihan Formation at Phu Faek, in Changwat Kalasin. The site, which will be described only briefly here, is a sandstone outcrop in a river bed (Fig. 2). It shows one main trackway, consisting of seven footprints, four of which are in fairly good condition while the others are weathered. Three additional trackways consisting of smaller footprints « cross » the main one at nearly right angles. All the footprints are three-toed. Those in the main trackway show long, relatively slender toes, which suggest that they were left by a theropod. The size of the footprints (45 cm long) suggests a rather large animal, a little more than 2 metres tall at the hip on the basis of Thulborn's equations (Thulborn, 1990), apparently moving at a rather low speed to judge from the relatively short stride length.



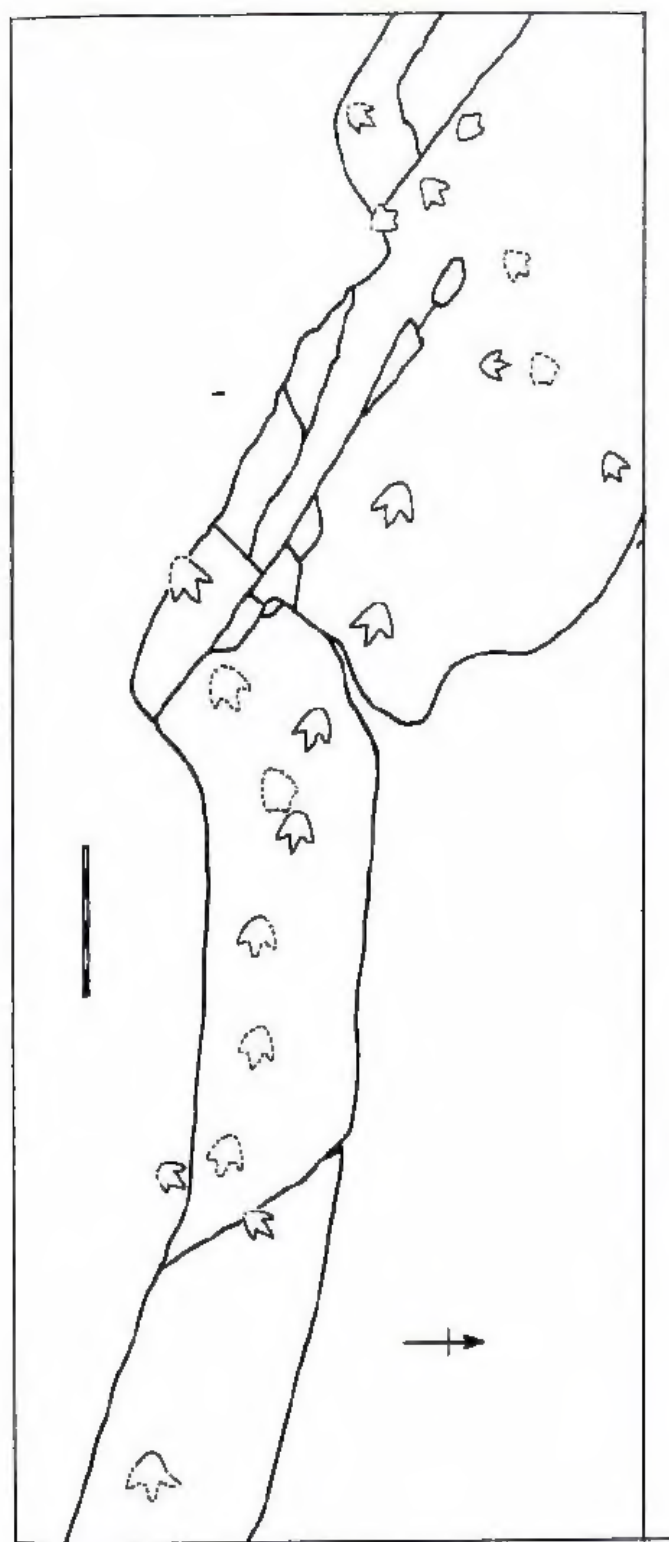


Figure 2 The dinosaur footprint site in the Phra Wihan Formation at Phu Faek (Changwat Kalasin). The main trackway was made by a large theropod dinosaur, probably a little more than 2 m high at the hip. Scale bar : 150 cm.

### New dinosaur discoveries from the Sao Khua Formation

The first Thai dinosaurs were discovered in the Sao Khua Formation, at Phu Wiang, in 1976, and since then a large number of new

finds have considerably enlarged our knowledge of this important faunal assemblage. As mentioned above, palynological results (Racey *et al.*, 1994, 1996) lead to consider the Sao Khua Formation as Early Cretaceous in age (since the underlying Phra Wihan Formation contains Early Cretaceous palynomorphs), rather than Late Jurassic, as was previously believed, and this new dating contributes to a better understanding of the real significance of the dinosaurs from the Sao Khua Formation, which is probably Valanginian to Barremian in age. Very few dinosaur assemblages of a similar age are currently known in Asia (see Jerzykiewicz & Russell, 1991, for a review of faunas from the Gobi Basin, and Dong, 1992, for a review of Chinese faunas). It now appears that several groups of dinosaurs which played an important part in Late Cretaceous faunas in Asia, and in some cases in North America, had early representatives in the Early Cretaceous of Thailand.

This was exemplified by the discovery of a partial skeleton of a large theropod dinosaur (estimated total length about 6.5 m) at site Phu Wiang 9, which was described as *Siamotyrannus isanensis* (Buffetaut, Suteethorn & Tong, 1996). The pelvis and parts of the vertebral column are known (Fig. 3). They show a combination of primitive features (such as an obturator hook on the pubis) and derived tyrannosaurid characters (such as an incipient anterior horizontal shelf on the ilium, and a particular muscle insertion scar on the ischium) which lead to consider *Siamotyrannus* as both the earliest and the most primitive known tyrannosaurid. A well preserved tibia, also found at Phu Wiang, shows the characters to be expected in an early tyrannosaurid, and probably also belongs to *Siamotyrannus*. The oldest hitherto known tyrannosaurids were from the beginning of the Late Cretaceous, both in Asia (*Alectrosaurus* from Iren Dabasu, also known as Erenhot, Inner Mongolia : Gilmore, 1933 ; Mader & Bradley, 1989) and in North America (teeth from the Upper Cedar Mountain Formation of Utah : Kirkland, 1996). *Siamotyrannus isanensis* antedates those Asian and North American tyrannosaurids by at least

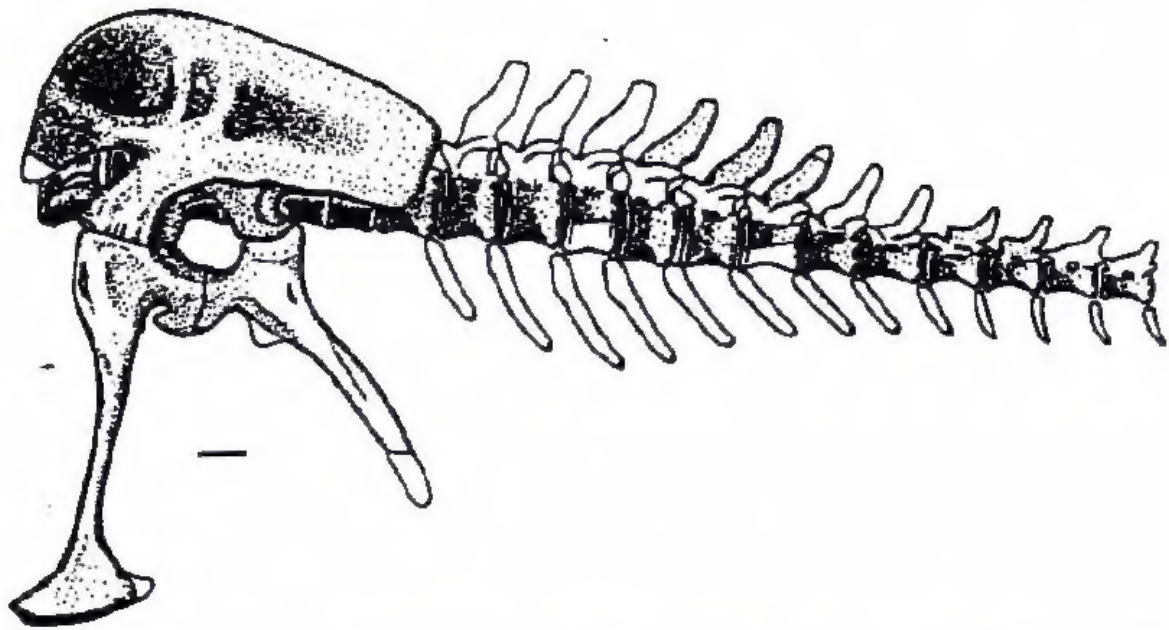


Figure 3 Reconstruction of the pelvis and part of the tail of *Siamotyrannus isanensis*, the earliest and most primitive known tyrannosaur, from the Sao Khua Formation at Phu Wiang (after Buffetaut et al., 1996). Scale bar : 10 cm.

15 or 20 million years. No convincing tyrannosaurid remains of such antiquity have been reported from anywhere else in the world. Because, as mentioned above, the record for that particular time span from other parts of Asia is very scanty, this does not mean that early tyrannosaurids were restricted to South East Asia, but it seems likely that the family originated in Asia and spread to North America only later (as already suggested by Russell, 1993), probably during the phase of interchange at the end of the Early Cretaceous suggested by North American data (Kirkland, 1996).

Another important theropod dinosaur from the Sao Khua Formation is a small ornithomimosaur, or « ostrich-dinosaur », the remains of which have been found at site Phu Wiang 5. Although no skull bones have so far been found, a number of post-cranial elements have been discovered, and they allow a reconstruction of such important parts of the skeleton as the metatarsus (Fig. 4). The ornithomimosaur from Phu Wiang, which has not yet been named, certainly represents a new taxon. Reports of earlier, Late Triassic or Jurassic, ornithomimosaur are either doubtful or based on material that cannot be compared

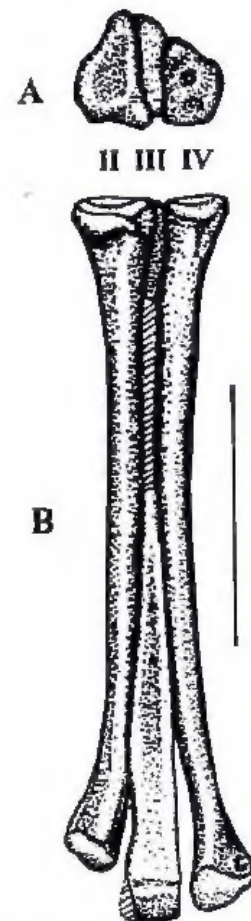


Figure 4 Reconstruction of the metatarsus of the new ornithomimosaur from the Sao Khua Formation at Phu Wiang, showing the proximally reduced third metatarsal, in proximal (A) and anterior (B) views (drawings by H. Tong). Scale bar : 5 cm.



with the Thai specimens (for lack of common elements), so comparisons have been made mainly with other Cretaceous forms, mostly on the basis of the metatarsus, which is a good indicator of the degree of evolutionary development in ornithomimosaurs. In *Harpymimus okladnikovi*, from the Aptian-Albian of Mongolia (Barsbold & Perle, 1984) and in *Garudimimus brevipes*, from the Cenomanian-Turonian of Mongolia (Barsbold, 1981), which are considered as some of the most primitive known ornithomimosaurs, the shaft of the third metatarsal is more or less D-shaped in cross-section, instead of triangular as in more advanced ornithomimosaurs and the new Thai form. Although laterally compressed, the proximal end of the third metatarsal is still broad enough in both *Harpymimus* and *Garudimimus* to be clearly visible in anterior view between the second and fourth metatarsals. In the Thai form, the proximal end of the third metatarsal is still visible in anterior view, but it is so narrow that it only forms a thin sliver of bone between the other metatarsals. In this regard, it is more advanced than *Harpymimus* and *Garudimimus*, but less so than other, Late Cretaceous, ornithomimosaurs, including the relatively primitive *Archaeornithomimus asiaticus* (Gilmore, 1933; Smith & Galton, 1990) from Iren Dabasu in Inner Mongolia, in which the proximal ends of the second and fourth metatarsals meet anteriorly, thus completely hiding the third metatarsal. The Thai ornithomimosaur is also relatively primitive in having a rather short metatarsus relative to the length of the tibia. All in all, although it is more primitive than the typical «advanced» ornithomimosaurs of the Late Cretaceous (sometimes placed in the family Ornithomimidae, as opposed to the more primitive Harpymimidae and Garudimimidae: see Barsbold and Osmolska, 1990) the Thai ornithomimosaur appears to be more advanced than the geologically younger *Harpymimus* and *Garudimimus*. This seems to indicate an early differentiation of advanced ornithomimosaurs in the Early Cretaceous, and a possible Asian origin of the Ornithomimidae, with a subsequent biogeographical history more or less similar to that of the Tyrannosauridae.

Sauropods were the first group of dinosaurs to be reported from Thailand and the majority of the dinosaur remains hitherto found in the Sao Khua Formation belongs to this group. In 1994, the new genus and species *Phuwiangosaurus sirindhornae* was erected by Martin, Buffetaut and Suteethorn on the basis of an incomplete skeleton from site Phu Wiang 1. Since then, a spectacular discovery at Wat Sakawan (Amphoe Sahat Sakhan, Changwat Kalasin) has provided a considerable amount of new information concerning the sauropods from the Sao Khua Formation. There, an accumulation of several more or less articulated sauropod skeletons (Fig. 5) has been discovered (Suteethorn *et al.*, 1995). At least two of the skeletons, apparently referable to *Phuwiangosaurus*, are almost complete, and, when completely prepared and studied, will make this genus one of the best known of Cretaceous sauropods. Parts which were incompletely known from the previously available material from Phu Wiang and other localities of the Khorat Plateau, such as the tail, the sacrum, or the hand and foot, are well represented at Wat Sakawan. Of particular interest are some jaw fragments and teeth, probably belonging to *Phuwiangosaurus*, from that locality. The teeth are long, slender and lanceolate. They are quite unlike the broad spoon-shaped teeth of the above-mentioned Euhelopodidae from the Jurassic of China (such as *Euhelopus* and *Mamenchisaurus*), and the newly discovered teeth from the Phu Kradung Formation. As far as teeth are concerned, the closest resemblances seem to be with those of *Nemegtosaurus mongoliensis*, a sauropod described by Nowinski (1971) from the Upper Cretaceous of Mongolia. However, *Nemegtosaurus* is known only from a skull, whereas *Phuwiangosaurus* is mainly known from its postcranial skeleton. Interesting comparisons may become possible when a recently discovered sauropod skeleton from the Upper Cretaceous of China (Pang *et al.*, 1995), which is reported to have *Nemegtosaurus*-like teeth, is described in detail. There seems to be a distinct possibility that *Phuwiangosaurus* may be close to the ancestry of some of the still poorly known Late Cretaceous sauropods of



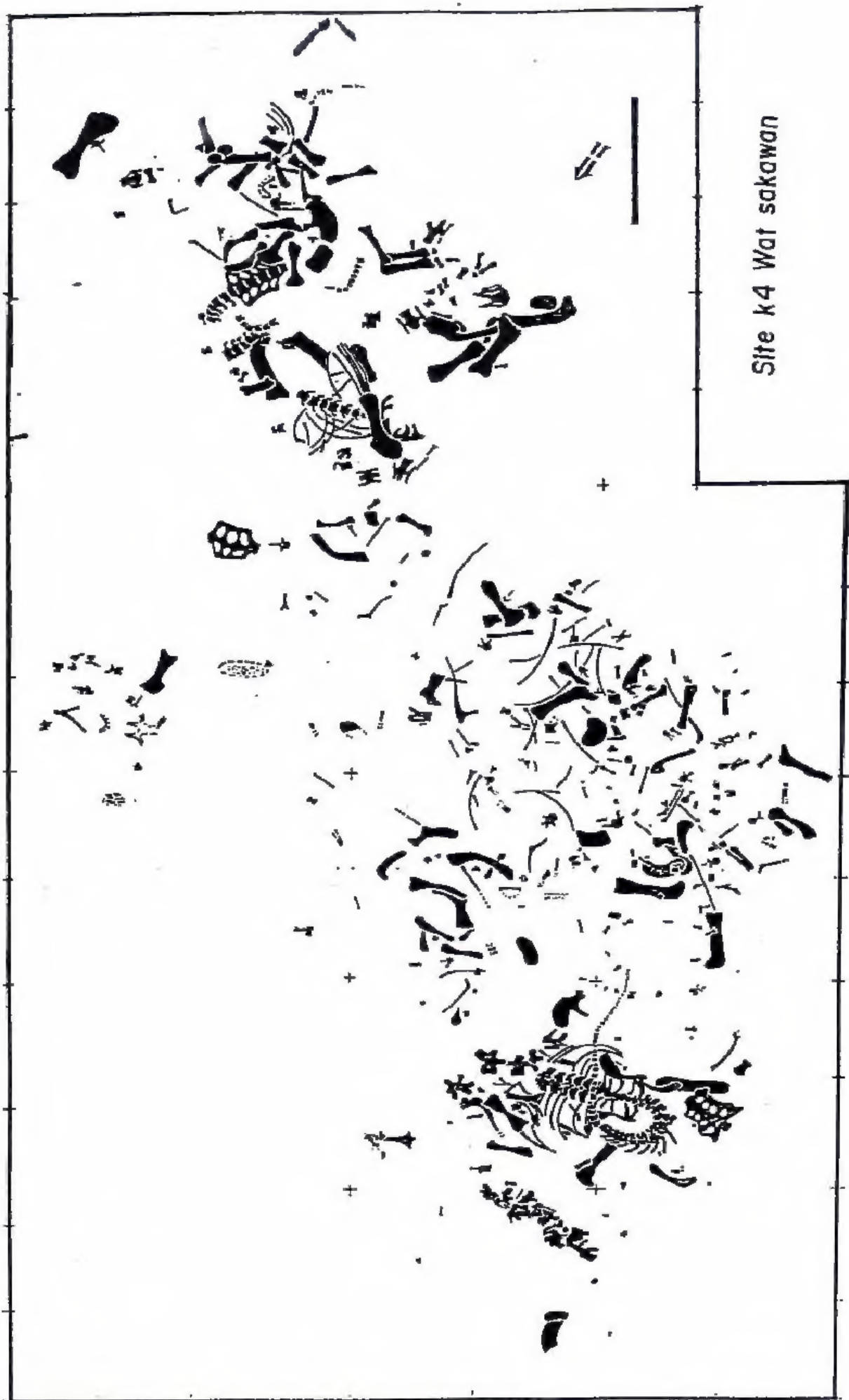


Figure 5 A plan of the excavated surface of the dinosaur site at Wat Sakawan (*Amphoe Sahat Sakhan, Changwat Kalasin*), showing several more or less articulated skeletons of the sauropod *Phuwiangosaurus*, together with a few elements apparently belonging to a second species of sauropod. Scale bar : 2 metres.

Asia (placed in the family Nemegtosauridae by Upchurch, 1994).

Of considerable interest, too, is the fact that a second sauropod, clearly distinct from *Phuwiangosaurus*, is present at Wat Sakawan. It is represented, so far, by only a jaw fragment bearing heavy broad teeth quite different from those of *Phuwiangosaurus*, and by some large limb bones, notably a long humerus which is somewhat reminiscent of the Brachiosauridae. A more detailed study is needed, however, before the precise affinities of this second sauropod can be elucidated, but its occurrence demonstrates that sauropod diversity in South East Asia in the Early Cretaceous was greater than was suspected some years ago. Clearly, sauropods still played a very important part in the terrestrial ecosystems of South East Asia in the Early Cretaceous.

#### Iguanodontids from the Khok Kruat Formation

The Khok Kruat Formation, at the top of the Khorat Group (if one follows recent interpretations according to which the Maha Sarakham Formation is separated from the underlying Khok Kruat Formation by an unconformity: Sattayarak, Srigulwong & Patarametha, 1991; Sattayarak, Polachan & Charusirisawad, 1991; Racey *et al.*, 1996), is referred to the Aptian-Albian on the basis of vertebrates (Cappetta *et al.*, 1990). The overlying Maha Sarakham Formation contains Albian-Cenomanian pollen (Sattayarak, Polachan & Charusirisawad, 1991). According to Racey *et al.* (1996), an Aptian age seems likely.

Although dinosaur remains have been known from the Khok Kruat Formation for a long time (see Buffetaut, 1983), the first remains to be found were teeth and bone fragments which could only be assigned to indeterminate theropods. Jaws of the small ceratopsian *Psittacosaurus* were then described from Ban Dong Bang Noi, near Chaiyaphum, as a new species, *P. sattayarakii* (Buffetaut & Suteethorn, 1992). The occurrence of this

animal is indicative of faunal relationships with northern Asia (Buffetaut *et al.*, 1989).

In 1997, more dinosaur remains were found in the Khok Kruat Formation at Khok Pha Suam, NE of Ubon Ratchathani. They include a tooth resembling the enigmatic *Siamosaurus suteethorni*, otherwise known from many localities in the Sao Khua Formation (Buffetaut & Ingavat, 1986), and several specimens belonging to iguanodontid ornithopods. Besides a caudal centrum resembling those of iguanodontids, the material includes several small severely worn shed teeth (Fig. 6). They closely resemble worn *Iguanodon* teeth from the Wealden of England figured by Mantell (1848) and Norman (1986), and worn and shed iguanodontid teeth from the Tetori Group of Japan described by Hasegawa *et al.* (1995). The crown is much abraded, and the root is

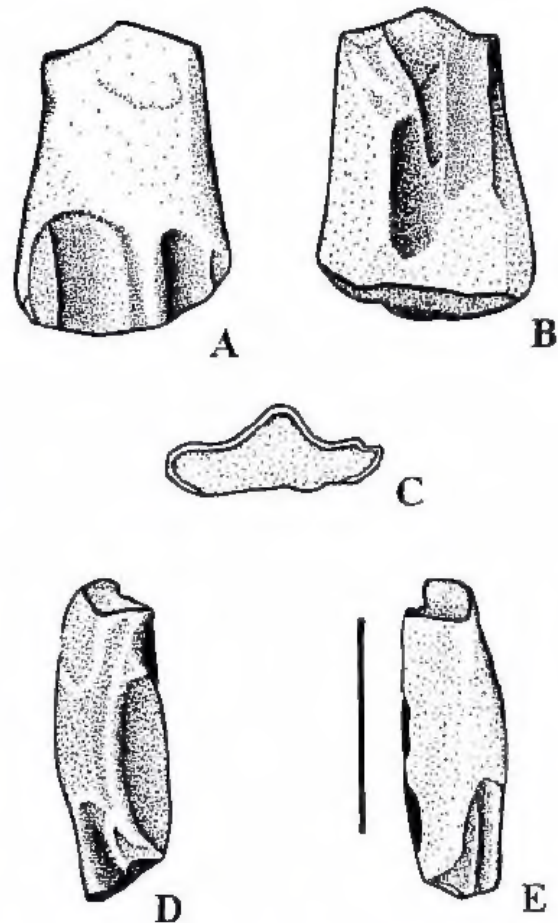


Figure 6 Worn iguanodontid tooth from the Khok Kruat Formation at Khok Pha Suam (Changwat Ubon Ratchathani) in lingual (A), labial (B), occlusal (C), anterior (D) and posterior (E) views (drawings by H. Tong). Scale bar: 1cm.



largely resorbed due to the development of the replacement tooth. Despite this high degree of wear, those teeth are clearly identifiable as belonging to iguanodontids, notably because of the pattern of ridges on what is left of the crown (with one well marked primary ridge, suggesting that they are teeth from the upper jaw). No identification below the family level is possible on the basis of the available material, however. These remains are the first firm evidence of ornithomimid dinosaurs from Thailand. Ornithomimids were described from Muang Phalane, in the Donghen Basin near Savannakhet in Laos, by Hoffet (1944), who erroneously thought that they were those of Late Cretaceous hadrosaurs. It was suggested by Buffetaut (1991) that the Muang Phalane dinosaur-bearing beds are an equivalent of the Khok Kruat Formation, and that the ornithomimids found there may have been iguanodontids rather than hadrosaurids. Taquet *et al.* (1995) have confirmed that the ornithomimids from Laos are iguanodontids, not hadrosaurids. The discovery of iguanodontids in the Khok Kruat Formation at Khok Pha Suam confirms that the Lao dinosaurs in all likelihood come from beds which can be equated with the Khok Kruat Formation, a conclusion supported by the stratigraphic succession in the Donghen Basin, where the dinosaur-bearing red beds are overlain by a salt formation (Vu Khuc & Le Thi Nghinh, 1996) which is very probably the equivalent of the Maha Sarakham Formation of Thailand.

It is interesting to contrast the dinosaur assemblage from the Khok Kruat Formation with that from the Sao Khua Formation. Whereas no well ascertained remains of ornithomimids have so far been identified among the hundreds of dinosaur bones found in the Sao Khua Formation, the Khok Kruat Formation contains both psittacosaurids and iguanodontids. It seems that both groups first appeared in South East Asia during the time interval between the deposition of the Sao Khua Formation (probably rather early in the Early Cretaceous) and that of the Khok Kruat Formation (Aptian to Albian). The occurrence

of *Psittacosaurus* in the Khok Kruat Formation is not stratigraphically surprising, since it is known from probably even older deposits in the Gobi Basin (Jerzykiewicz & Russell, 1991). The discovery of *Psittacosaurus* in South East Asia has caused some surprise (Dodson, 1996), because this dinosaur, having been found in Mongolia, Siberia and northern China, was usually considered as characteristic of a northern Asian bioprovince (Dong, 1993). However, this probably mainly emphasizes how little is known about the Early Cretaceous of South China (Dong, 1993).

Iguanodontids make their first appearance in the Gobi Basin during the Khukhtekian « Age » of Jerzykiewicz and Russell (1991), which is considered by those authors as probably corresponding to the late Aptian and early Albian. They are considered by Russell (1993) as possible immigrants from Europe, after the end of the isolation of Asia. The Thai record is thus in fairly good agreement with the one from the Gobi Basin. Iguanodontids, as mentioned above, are also known from the Early Cretaceous Tetori Group of Japan. According to Hasegawa *et al.* (1995), however, the Japanese iguanodontids are « Early Neocomian » in age, and therefore older than those from Thailand and the Gobi Basin. This age assignment is based on the fact that the iguanodontid-bearing formation in Japan is overlain by a formation referred to the late Barremian-Albian, on the basis of molluscs (Hasegawa *et al.*, 1995). The Japanese record of iguanodontids can be reconciled with the Thai one if one accepts that the Sao Khua Formation, which apparently contains no iguanodontids, is older than Barremian, which it may well be. There remains a discrepancy between the Japanese record and that from the Gobi basin, where no iguanodontids are known from the Tsagantsabian and Shinkhudukian ages, which are supposed to range in age from Valanginian to Aptian (Jerzykiewicz & Russell, 1991). If Asian iguanodontids are indeed immigrants from Europe, which seems likely since *Iguanodon orientalis* from Mongolia appears to be a junior synonym of *I. bernissartensis* from Europe (Norman, 1996), it seems difficult to



explain how they can have reached Japan before they reached the Gobi area. There is therefore an interesting correlation problem between the Early Cretaceous vertebrate faunas of Thailand, the Gobi Basin and Japan. It is hoped that further discoveries in the Khok Kruat Formation may help to clarify it.

## CONCLUSION

The recent dinosaur discoveries briefly described above confirm the great importance of Thai localities for our understanding of dinosaur evolution in Asia. The fauna from the Sao Khua Formation is of particular importance because of its age: it apparently fills a gap, corresponding to an early part of the Early Cretaceous, in the record of Asian dinosaurs, between the rich Jurassic assemblages from China and the succession of Cretaceous assemblages from the Gobi Basin, which seems to begin slightly later than the time span corresponding to the deposition of the Sao Khua Formation. It appears that several groups of dinosaurs which were later to play an important part in Late Cretaceous faunas in Asia (and, in some cases, in North America), such as the *Tyrannosauridae*, the advanced *ornithomimosaurs* and possibly the *Nemegtosauridae*, have early representatives in the Sao Khua Formation. The remarkable locality at Wat Sakawan will undoubtedly yield a wealth of data about the Early Cretaceous sauropods of Asia.

Although less abundant and complete, the dinosaur remains from the Phu Kradung and Khok Kruat Formations are no less interesting. The Phu Kradung Formation is beginning to yield the first truly Jurassic dinosaurs from Thailand, and comparisons with the Chinese faunas may result in interesting biogeographical conclusions. As to the dinosaurs from the Khok Kruat Formation, they reveal the importance of the faunal change which took place in Asia sometime during the Early Cretaceous, between the deposition of the Sao Khua Formation and that of the Khok Kruat Formation. This change may be the combined result of the local

evolution of forms such as *psittacosaurids* (from admittedly unknown ancestors) and of the immigration into Asia of forms such as *iguanodontids*, when Asia ceased to be isolated from other land masses by seaways.

However, the important results obtained in recent years concerning the dinosaurs of Thailand should not obscure the fact that much remains to be done. All the dinosaur assemblages from Thailand, including the one from the Sao Khua Formation, are still very incompletely known by comparison with some other faunas from other parts of the world (including those from the Jurassic of China and from the Upper Cretaceous of Mongolia and China). Continued prospecting and systematic excavations will no doubt considerably increase our present knowledge of Thai dinosaurs in the future.

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